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(54) **COMMUNICATION APPARATUS, COMMUNICATION SYSTEM, AND COMPUTER PROGRAM PRODUCT**

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Jan. 22, 2013 (JP) 2013-009567

(51) **Int. Cl.**

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H04L 9/08	(2006.01)

(52) **U.S. Cl.**

CPC ***H04L 63/06*** (2013.01); ***H04L 9/0816*** (2013.01); ***H04L 9/0819*** (2013.01); ***H04L 9/0822*** (2013.01); ***H04L 63/04*** (2013.01); ***H04L 63/0428*** (2013.01); ***H04L 63/0435*** (2013.01)

(58) **Field of Classification Search**

CPC H04L 9/08; H04L 63/04; H04L 63/06
USPC 713/150–175; 380/255–30
See application file for complete search history.

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(57) **ABSTRACT**

According to an embodiment, a communication apparatus includes a sharing processing unit, an extension unit, and a communication unit. The sharing processing unit shares a first cryptographic key with an external apparatus connected via a link, and further generates a second cryptographic key and shares the second cryptographic key with the external apparatus through secret communication using the first cryptographic key. The extension unit generates an extended key by extending a length of the second cryptographic key. The communication unit transmits the extended key to a first application which communicates with a second application to which the external apparatus provides the second cryptographic key.

10 Claims, 4 Drawing Sheets

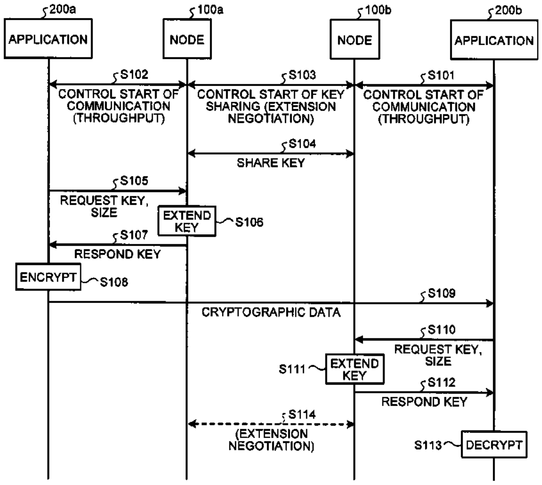


FIG.1

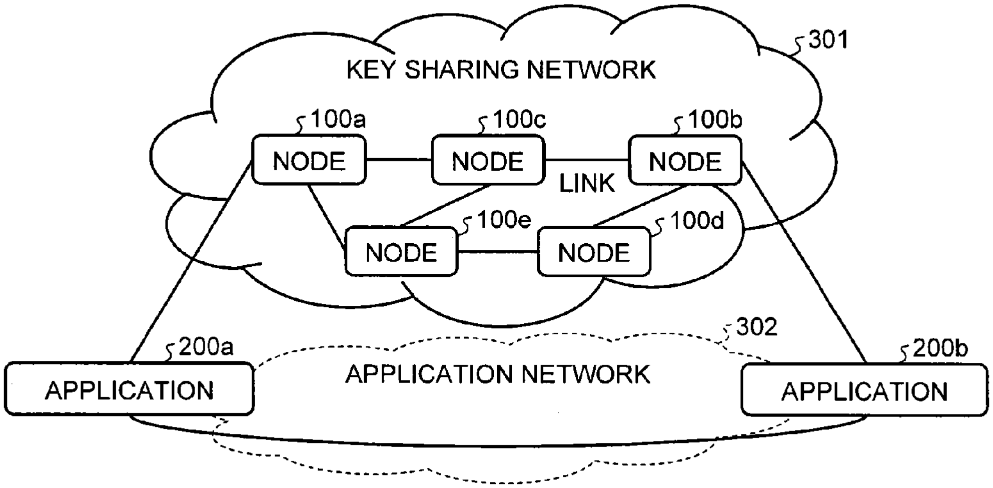

301
KEY SHARING NETWORK
100a
NODE
100c
NODE
100b
NODE
LINK
100e
NODE
100d
NODE
302
200a
APPLICATION
APPLICATION NETWORK
200b
APPLICATION

FIG.2

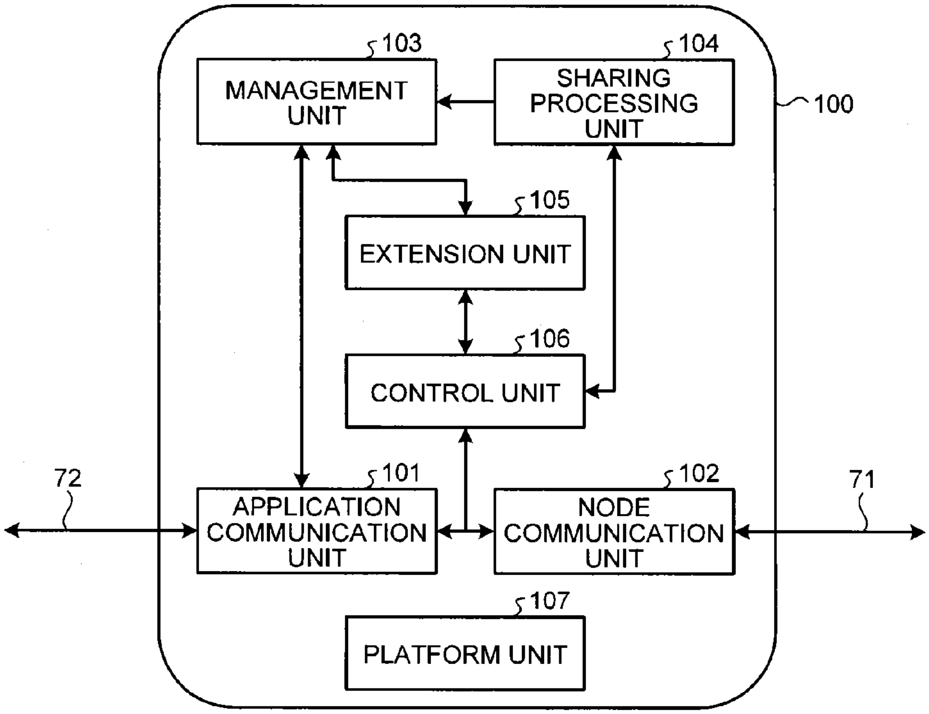

103
MANAGEMENT UNIT
104
SHARING PROCESSING UNIT
100
105
EXTENSION UNIT
106
CONTROL UNIT
72
101
APPLICATION COMMUNICATION UNIT
102
NODE COMMUNICATION UNIT
71
107
PLATFORM UNIT

FIG.3

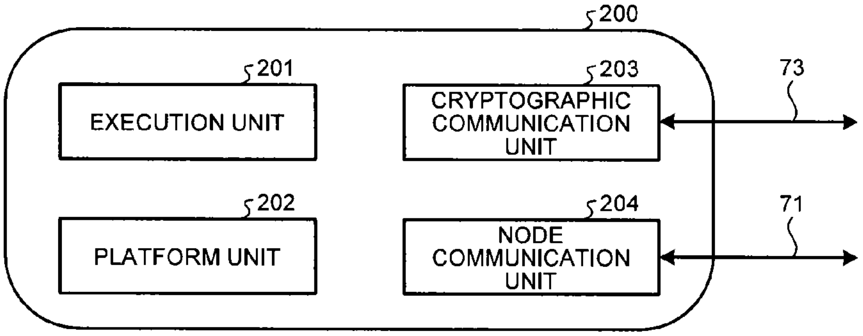

200
201
EXECUTION UNIT
203
CRYPTOGRAPHIC COMMUNICATION UNIT
73
202
PLATFORM UNIT
204
NODE COMMUNICATION UNIT
71

FIG.4

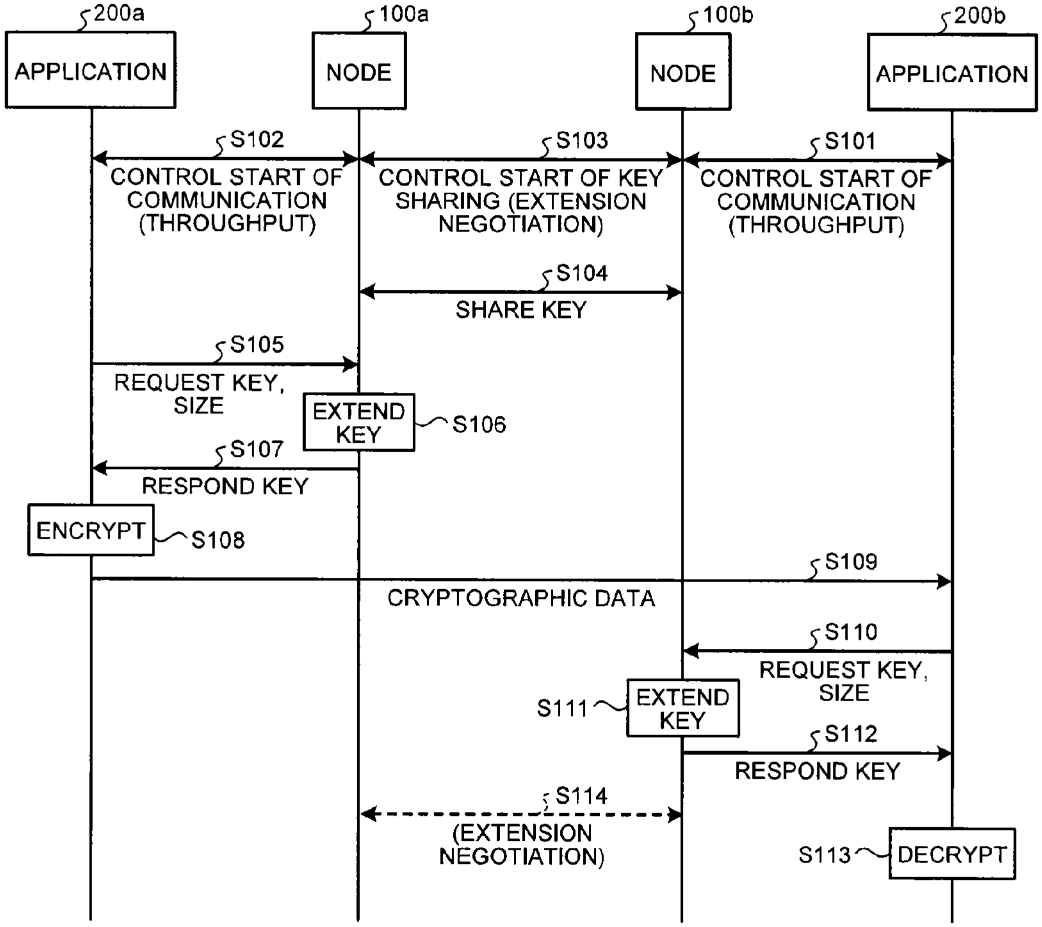

200a
APPLICATION
100a
NODE
100b
NODE
200b
APPLICATION
S102
CONTROL START OF COMMUNICATION (THROUGHPUT)
S103
CONTROL START OF KEY SHARING (EXTENSION NEGOTIATION)
S101
CONTROL START OF COMMUNICATION (THROUGHPUT)
S104
SHARE KEY
S105
REQUEST KEY, SIZE
EXTEND KEY
S106
S107
RESPOND KEY
ENCRYPT
S108
S109
CRYPTOGRAPHIC DATA
S110
REQUEST KEY, SIZE
S111
EXTEND KEY
S112
RESPOND KEY
S114
(EXTENSION NEGOTIATION)
S113
DECRYPT

FIG.5

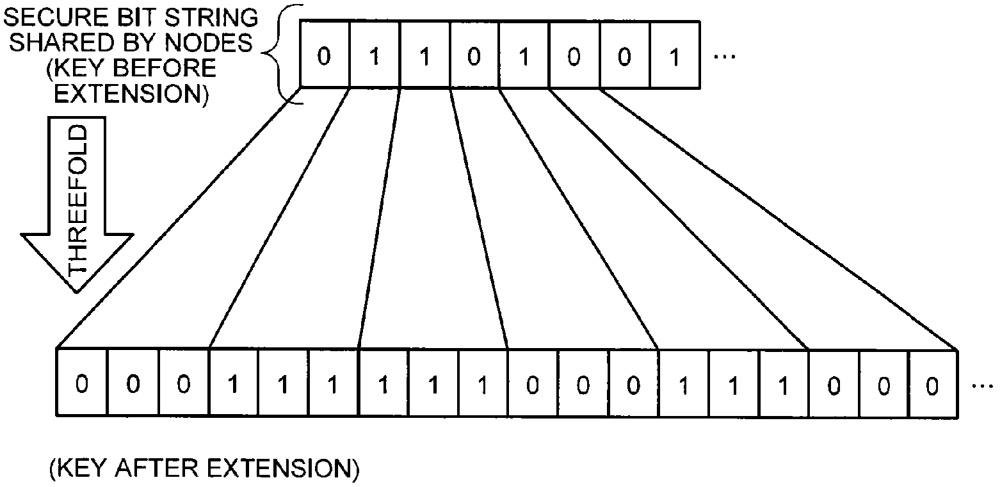

SECURE BIT STRING SHARED BY NODES (KEY BEFORE EXTENSION)
0 1 1 0 1 0 0 1 ···
THREEFOLD
0 0 0 1 1 1 1 1 1 0 0 0 1 1 1 0 0 0 ···
(KEY AFTER EXTENSION)

FIG.6

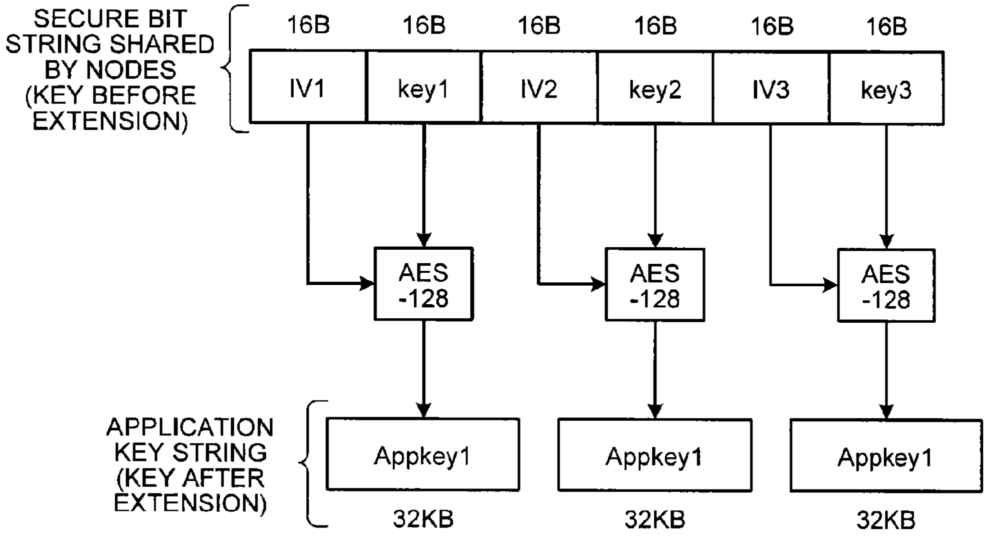
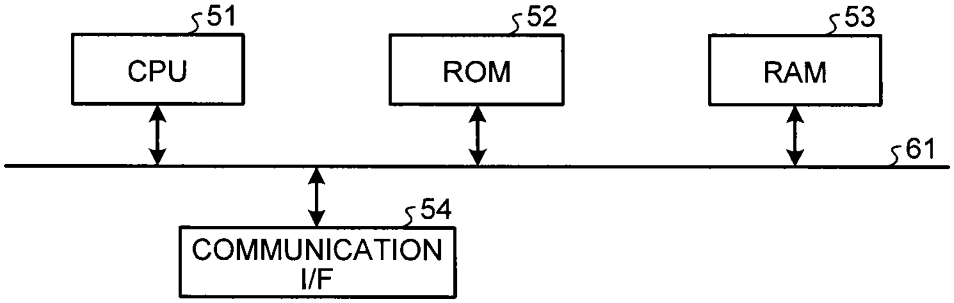

SECURE BIT STRING SHARED BY NODES (KEY BEFORE EXTENSION)
16B
16B
16B
16B
16B
16B
IV1
key1
IV2
key2
IV3
key3
AES -128
AES -128
AES -128
APPLICATION KEY STRING (KEY AFTER EXTENSION)
Appkey1
Appkey1
Appkey1
32KB
32KB
32KB

FIG.7



COMMUNICATION APPARATUS, COMMUNICATION SYSTEM, AND COMPUTER PROGRAM PRODUCT

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2013-009567, filed on Jan. 22, 2013; the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described herein relate generally to a communication apparatus, a communication system, and a computer program product.

BACKGROUND

A cryptographic communication network (a key sharing network) configured with a plurality of nodes, which is connected to each other through a plurality of links and networked, has been known. Each node has a function of generating and sharing a random number with opposite nodes that are connected via links, as well as has a function of performing cryptographic communication over a link by using a random number as a cryptographic key (hereinafter referred to as "a link key"). Further, some of the nodes also have a function of generating a cryptographic key (hereinafter referred to as "an application key") which is a random number independent of the links, as well as have a function of transmitting the generated application key to a different node via a link. An application in the key sharing network has a function of acquiring an application key from a node and, using the application key as a cryptographic key, performing cryptographic communication with another application. The cryptographic data communication at this time may be performed using a network (an application network) which is different from the key sharing network, such as the Internet. Meanwhile, applications and nodes may be configured in an integrated manner. Alternatively, applications and nodes may be configured as terminals independent of each other, and application keys may be transmitted and received among the application and nodes.

In a node, the function of generating a random number (a link key) and sharing it with opposite nodes that are connected through links may also be implemented using, for example, a technique which is commonly referred to as quantum cryptographic communication. In this case, a technique in which a random number (an application key) is generated in a node independently of a link and the generated random number is transmitted to another node via a link is sometimes referred to as quantum key distribution (QKD).

An application may want to acquire an application key from a node faster and more stably. Accordingly, a node has a need to provide an application key to an application faster and more stably without being affected by restrictions (low throughput, variation, and the like) in by the quantum cryptographic technique.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a network configuration diagram of a communication system according to a present embodiment;

FIG. **2** is a block diagram of a node in the present embodiment;

FIG. **3** is a block diagram of an application in the present embodiment;

FIG. **4** is a sequence diagram of cryptographic communication processing according to the present embodiment;

FIG. **5** is a diagram illustrating an example of an extension method of an application key;

FIG. **6** is a diagram illustrating an example of an extension method of the application key; and

FIG. **7** is a hardware configuration diagram of an apparatus according to the present embodiment.

DETAILED DESCRIPTION

According to an embodiment, a communication apparatus includes a sharing processing unit, an extension unit, and a communication unit. The sharing processing unit shares a first cryptographic key with an external apparatus connected via a link, and further generates a second cryptographic key and shares the second cryptographic key with the external apparatus through secret communication using the first cryptographic key. The extension unit generates an extended key by extending a length of the second cryptographic key. The communication unit transmits the extended key to a first application which communicates with a second application to which the external apparatus provides the second cryptographic key.

Referring to the accompanying drawings, a preferred embodiment of a communication apparatus will be described below in detail.

A speed (sharing speed), at which nodes connected to a key sharing network shares an application key, is restricted by a speed, at which a link key is exchanged and shared in an internode link over which the application key is transferred. Further, the sharing speed of the application key may determine a speed at which the application is able to acquire the application key. Accordingly, the sharing speed of the application key may restrict a maximum speed at which the application is able to conduct cryptographic communication. Particularly, when the application employs a cryptographic method utilizing an application key having the same length as data, which is called an OTP (One-time Pad), the speed at which the application is able to acquire the application key corresponds to a speed at which the application is capable of communicating. When the current quantum cryptographic technique is used, the speed at which the link key is exchanged and shared is at most less than a few Mbps. Moreover, the speed may also fluctuate depending on an installation environment of the apparatus.

Therefore, as described above, when the speed at which the link key is shared is small, or even when the speed at which the link key is shared fluctuates, it is desirable that the application key be provided faster and more stably.

FIG. **1** is a diagram illustrating a network configuration example of a communication system according to a present embodiment. The communication system includes a key sharing network **301** and an application network **302**. Further, the communication system includes nodes **100***a* to **100***e* serving as communication apparatuses and applications **200***a*, **200***b*.

If it is not necessary to distinguish the nodes **100***a* to **100***e*, there is a case in which a node **100** is simply used. If it is not necessary to distinguish the applications **200***a*, **200***b*, there is a case in which an application **200** is simply used. The number of nodes **100** is not limited to five. Moreover, the number of applications **200** is not limited to two. FIG. **1** is an example of a case in which the node **100** and the application **200** are independently implemented.

As described above, the nodes **100***a* to **100***e* have a function of generating a random number and sharing it with an opposite node, and a function of performing cryptographic communication over the link by using the generated random number as a link key.

The node **100** may have a function of generating a random number independently of the link, and a function of transmitting the generated random number to the other node.

FIG. **2** is a block diagram illustrating a configuration example of the node **100** in the present embodiment. The node **100** includes an application communication unit **101**, a node communication unit **102**, a management unit **103**, a sharing processing unit **104**, an extension unit **105**, a control unit **106**, and a platform unit **107**.

The node communication unit **102** generates a random number and shares it with an opposite node connected via an internode link **71** by using a quantum cryptographic communication technique, and manages the generated random number as a link key. Further, the node communication unit **102** is utilized when internode data communication is performed with the other node **100** connected via the internode link **71**. Here, the other node **100** may be an opposite node directly connected via the internode link **71**, or a different node **100** further connected to the opposite node via a different internode link **71** thereof. In the latter case, the node communication unit **102** may provide a routing function for performing communication through the plurality of nodes **100** in the cryptographic communication. Data exchanged between the nodes **100** through the node communication unit **102**, for example, is data of an application key. These data may be transmitted and received via encrypted communication (secret communication) by using the link key managed by the nodes **100**. It should be noted that only one node communication unit **102** is illustrated in FIG. **2**. However, the node communication unit **102** may be connected with the plurality of nodes **100** via the plurality of internode links **71**.

The sharing processing unit **104** generates an application key (cryptographic key) as a random number and shares it with the other node **100**. The application key, for example, is generated as a random number in a form to which identification data (ID) capable of identifying the application key is added. A format of the ID of the application key is not particularly specified. Hereinafter, it is assumed that an order is identified by successive numbers. The generated application key is stored in the management unit **103**. In response to an instruction from the control unit **106** or the like, the sharing processing unit **104** can encrypt the generated application key by using the node communication unit **102**, and transmit this to the other node **100** to share it therewith. Likewise, the sharing processing unit **104** receives the application key received from the other node **100** through the node communication unit **102**, and stores the received application key in the management unit **103**.

The management unit **103** stores and manages the application key. The application key stored in the management unit **103** is a key generated by the sharing processing unit **104** or a key received from the separate node **100** via the node communication unit **102**. The application key stored in the management unit **103** is one of the most important data for security in the cryptographic communication system. For this reason, security measures, such as encryptions, tamper-preventions, and access restrictions, may be taken by a file system or an OS (operating system). Although various implementation methods are possible for the management unit **103**, the management unit **103** can be mounted, for example, as a file system or a data base.

The extension unit **105** generates an extended key by extending the application key stored in the management unit **103** according to predetermined rules (i.e., a key length is increased). An example of processing of extending the key will be described later. The extension unit **105** may store again the extended application key in the management unit **103**. Further, when the application communication unit **101** acquires the application key from the management unit **103**, the application key may be extended by using the extension unit **105**, and the extended key obtained by the extension may be provided to the application through the application communication unit **101**. Moreover, when the sharing processing unit **104** stores the generated or received application key in the management unit **103**, the application key may be extended by using the extension unit **105**, and the result may be stored in the management unit **103**.

The application communication unit **101** connects and communicates with the application **200** via an application communication link **72**. The application communication unit **101** receives requests from the application **200**, for example, a cryptographic communication starting request (i.e., an application key provision starting request), a cryptographic communication ending request (i.e., an application key provision ending request), and an application key acquiring request. The application communication unit **101** provides the extended key, which is obtained by extending the application key, to the application **200** according to the request from the application. The extended key provided to the application **200** (or the application key from which the extended key is obtained) may be deleted from the management unit **103**.

The control unit **106** controls the above-described units implementing the functions of the node **100**, and executes a series of the application key sharing operations in the key sharing network. For example, the control unit **106** instructs and controls the sharing processing unit **104** to share the application key. Further, the control unit **106** has functions of performing communication with the node **100** (partner node) which shares the application key, and determining and changing the operation of the key extension. For example, the control unit **106** exchanges information about an extension method of the application key with the partner node and determines the extension method to be applied. Then, the control unit **106** controls the extension unit **105** so as to synchronize with the other node **100** and execute the extension processing according to the determined extension method. The processing of determining the extension method set for the extension unit **105** by exchanging the information about the extension method of the application key with the other node **100** is referred to as negotiation about key extension.

The platform unit **107** provides management of the other components on the node **100**, an operating system function of a computer necessary for the operation, a basic network function, a security function, and the like.

A configuration of the node **100** in the present embodiment has been described above. However, the above description is one example.

Next, the application **200** in the present embodiment will be described. FIG. **3** is a block diagram illustrating a configuration example of the application **200** in the present embodiment. The application **200** includes a node communication unit **204**, a cryptographic communication unit **203**, an execution unit **201**, and a platform unit **202**.

The node communication unit **204** connects and communicates with the node **100** (the application communication unit **101** on the node **100**) via the internode link **71**. The node communication unit **204**, for example, acquires the application key necessary for performing cryptographic communication from the node **100**. In the present embodiment, the node communication unit **204** acquires the extended key, which is the application key extended by the extension unit **105** as described above, from the node **100**. The node communication unit **204** transmits to the node **100** an acquisition starting request of the extended key before starting the acquisition of the extended key, and an ending request when the acquisition of the extended key ends. Further, the node communication unit **204** stores and manages the acquired extended key. The extended key stored by the node communication unit **204** is used by the cryptographic communication unit **203**. Upon receiving the request of the extended key from the cryptographic communication unit **203**, the node communication unit **204** provides the stored extended key to the cryptographic communication unit **203**.

The execution unit **201** executes an application function of performing cryptographic communication. The type of the application function is not particularly limited as long as the communication is performed. For example, the execution unit **201** executes a function of transmitting and receiving a video image or the like. Upon the cryptographic communication, the execution unit **201** transmits and receives data by utilizing the cryptographic communication unit **203**.

The cryptographic communication unit **203** provides a communication function necessary for the operation of the execution unit **201**, an encryption function of communication data, and a decryption function of the communication data. Upon receiving transmit data from the application **200**, the cryptographic communication unit **203** encrypts the received transmit data, and transmits the cryptographic data to the application network **302** via a cryptographic data communication link **73**. Further, upon receiving the data from the cryptographic data communication link **73** via the application network **302**, the cryptographic communication unit **203** decrypts the received data. The cryptographic communication unit **203** delivers the decrypted data to the execution unit **201**. When necessary for encryption and decryption, the cryptographic communication unit **203** acquires a new extended key from the node communication unit **204**.

In the present embodiment, a cryptographic algorithm used by the cryptographic communication unit **203** is not particularly limited. A Vernam cipher, such as an OTP, or a block cipher, such as an AES (Advanced Encryption Standard) may be used. However, the cryptographic communication unit **203** utilizes the extended key stored in the node communication unit **204** for cryptographic communication. Further, the cryptographic communication unit **203** may execute a data authentication function and a communication partner authentication function in addition to the encryption function.

The platform unit **202** provides management of the other components on the application **200**, an operating system function of a computer necessary for the operation, a basic network function, a security function, and the like.

A configuration of the application **200** in the present embodiment has been described above. However, the above description is one example.

Next, a basic sequence of cryptographic communication processing according to the present embodiment will be described. FIG. **4** is a sequence diagram illustrating an example of the cryptographic communication processing according to the present embodiment. A situation in which the application **200***a* connected to the node **100***a* performs cryptographic communication with the application **200***b* connected to the node **100***b* is assumed below. It should be noted that the node **100***a* and the node **100***b* may be directly connected via the internode link **71** or may be connected via the other nodes **100** (the nodes **100***c* to **100***e*).

First, the application **200***b* notifies the node **100***b*, to which the application **200***b* is connected, that the start of communication is in a receivable state and of information of type of communication which is receivable (e.g., a port number receiving the start of communication, information of a throughput capable of communicating, or the like). The node **100***b* manages the communication-capable state of the application **200***b*, and makes it sharable with the other node **100**. Subsequently, the application **200***b* is actually in a state in which the start of cryptographic data communication is receivable (step S**101**).

Next, the application **200***a* controls the start of communication (step S**102**). The application **200***a*, for example, notifies the node **100***a*, to which the application **200***a* is connected, of a communication starting request. At this time, the application **200***a* specifies address information, a port number, and the like of the application **200***b*. Besides specifying the address and the like, the application **200***a* may notify of information (request throughput) about a throughput (utilization rate of an application key to be requested or the like) in case of acquiring the application key. The request throughput may be previously set to the application **200***a* by a user. Further, upon executing the application function, the application **200***a* may record data which has been transmitted through cryptographic communication and information of a communication speed, and the application **200***a* may determine a request throughput. For example, when an application function of sending a video is operated and an OTP is utilized for encryption, a bit rate of the video can become a request throughput without any change.

When the node **100***a* receives the communication starting request from the application **200***a* connected thereto, the node **100***a* controls the start of key sharing. In order to provide the application key (extended key) used in the requested cryptographic communication, the node **100***a* specifies the node **100** (herein, the node **100***b*), which serves as a target of performing the key sharing, by retrieving address information of the application which is managed by each node and is in the communication-capable state or the like, and then performs communication. The state in which the key sharing is executable is initialized between the nodes. Simultaneously, the node **100***a* and the node **100***b* perform negotiation of the extension processing of the key, which will be described below (step S**103**). It should be noted that, at this time, the node **100***b* may notify the application **200***b* of the request throughput notified from the application **200***a*, the address information of the application **200***a*, or the like. Upon reception of this information, the application **200***b* can reject the communication starting request from the application **200***a*.

When the key sharing start control is completed in step S**103**, the node **100***a* actually shares the application key with the specified node **100***b* (step S**104**).

When the request throughput (the utilization rate of the application key to be requested or the like) is notified from the application **200***a*, the control unit **106** of the node **100***a* may perform control so as to share the application key at a speed satisfying the request throughput. After the series of sharing processing of the application key has been started, the node **100***a* may return to the application **200***a* a response that the sharing of the application key has been started.

The application **200***a* requests acquisition of the application key to the node **100***a* (step S**105**). The application **200***a* may transmit a size of the extended key to be used together with the request of the key. Upon receiving the request of the application key, the extension unit **105** of the node **100***a* extends the application key (step S**106**). The application communication unit **101** of the node **100***a* transmits the extended key obtained by the extension to the application **200***a* (step S**107**).

The application **200***a*, which has received the extended key, starts the cryptographic communication (transmission of the cryptographic data) with the application **200***b*. For example, the cryptographic communication unit **203** uses the extended key as a cryptographic key (application key) and encrypts data to be transmitted (step S**108**). The cryptographic communication unit **203** transmits the encrypted cryptographic data to the application **200***b* (step S**109**).

The application **200***b*, which has received the cryptographic data, requests the connected node **100***b* to acquire the application key (the extended key) for decrypting the cryptographic data (step S**110** to step S**112**). This processing is similar to step S**105** to step S**107**, which are executed by the application **200***a*. The cryptographic communication unit **203** of the application **200***b* decrypts the cryptographic data by using the acquired extended key (step S**113**). Accordingly, the cryptographic data communication is completed.

The above description is the basic sequence assumed in the present embodiment.

In the present embodiment, as illustrated in FIG. **4**, the communication (negotiation) for extending the application key may be conducted between the node **100***a* and the node **100***b* (step S**102**). The negotiation is performed when the control units **106** of the respective nodes **100** mutually communicate via the node communication unit **102**.

The plurality of applications **200** may be connected to the node **100**. For example, from such a reason, the node **100***a* may be requested to provide the application key to the application **200***a* at a throughput which exceeds a throughput of the application key which can be exchanged and shared with the node **100***b*. The control unit **106** of the node **100***a* determines necessary extension magnification of the application key based on, for example, a total request throughput requested by the application **200**, information of an actual sharing speed when the application key is exchanged and shared with the node **100***b*, and the like. The request throughput can be, for example, acquired from the application communication unit **101**. The information of the sharing speed can be, for example, acquired from the sharing processing unit **104**.

For instance, it is assumed that the sharing speed of the application key with the node **100***b* is 1 Mbps, and the total of the request throughput requested by the application **200***a* connected thereto is 5 Mbps. In this case, by extending the application key by five times or more, the request of the application key from the application **200***a* can be met. Further, the node **100***a* simultaneously determines the extension method of extending the application key. In this determination, extension magnification of the application key to be needed, an amount of calculation necessary for the extension of the application key, and a type of an application key extending algorithm of the node **100***a* are referred to.

The control unit **106** of the node **100***a* transmits information (hereinafter, referred to as "extension method data"), which indicates at least one extension method, to the node **100***b* via the node communication unit **204**. The extension method data, for example, includes extension magnification of the application key and information of an algorithm for executing the extension of the application key. An ID of the application key for indicating from which application key is subjected to the extension processing may be added to the extension method data. Further, the node **100***a* may transmit the plurality of extension method data, to which information of the priority order is added, to the node **100***b*. The node **100***b* may refer to the priority order and determine an extension method to be used from the plurality of extension method data.

The control unit **106** of the node **100***b*, which has received the extension method data, receives information of the extension method data via the node communication unit **204**, and knows the extension magnification and the extension algorithm of the corresponding application key, and the ID of the application key which starts extension, and the like. Upon reception of the plurality of extension method data, the control unit **106** of the node **100***b* may determine the extension algorithm and the extension magnification to be used based on the information of the extension algorithm to be supported, and return a determination result to the node **100***a*.

It should be noted that, when the extension cannot be started from the application key having the specified ID, the ID of the key which indicates the application key, to which the extension processing is actually applicable, may be added to the response of the determination result. For example, a case in which the application key having the specified ID has been already provided to the application **200** (without extension) corresponds to the case in which the extension cannot be started from the application key having the specified ID.

When the control unit **106** instructs the extension unit **105**, the node **100***b* starts the extension processing. The node **100***a*, which has received the response, determines the magnification, the extension algorithm, and the ID of the application key to be targeted for actually performing the extension processing, and starts the extension processing.

With such a configuration, the node **100***a* and the node **100***b* can start, from the application key having the same ID, the extension processing by the application key with the common extension algorithm and the common extension magnification. As a result, the node **100** can provide the application key which satisfies the request throughput requested by the application **200**.

It should be noted that, after the extension algorithm and the like are determined and the extension processing can be started, timing at which the extension processing is actually performed by the extension unit **105** has several variations. For example, a case in which the application keys stored in the management unit **103** are sequentially subjected to the extension processing, and a case in which, upon request of the application key from the application communication unit **101**, the extension processing of the requested application key is performed are considered. FIG. **4** illustrates the latter case.

It should be noted that FIG. **4** illustrates an example in which the control unit **106** starts negotiation of the extension processing simultaneously with or immediately after the sharing and exchanging processing of the application key is started between the node **100***a* and the node **100***b* (step S**101**, step S**102**). The timing at which the negotiation of the extension processing by the control unit **106** is performed is not limited to this.

As also illustrated in FIG. **4**, the extension negotiation of the application key by the control unit **106** of the node **100** may be performed during the sharing of the application key (step S**114**), and the extension processing may be newly started. Further, the determined extension method, magnification, and the like may be changed in the similar manner during the sharing of the application key. The control unit **106** may perform the extension negotiation at timing at which, for example, a different application **200** newly requests the start of communication and a sharing speed of the application key requested between the node **100***a* and the node **100***b* is increased.

Additionally, the control unit **106** may change the extension magnification and the extension method due to changes in the quantum cryptographic parameters observable by the node **100** such as, for example, a change in the sharing speed of the link key to be shared by the quantum cryptographic communication, the increase in an error rate of the quantum cryptographic communication, and the like. This is because the speed of the application key which can be actually shared between the node **100***a* and the node **100***b* is highly likely to be changed or reduced by these factors.

Further, the control unit **106** may be configured so as to previously assume the occurrence of variations in the quantum cryptographic parameters (e.g., a link key generating speed and an error rate) and determine in the extension negotiation a list of combinations of variation values of these quantum cryptographic parameters and the extension method data when the parameters are varied.

For example, a condition such as, "if a link generating speed is 100 kbps or less, the extension magnification is increased by 100 times", "if it is 500 kbps or less, the extension magnification is increased by 20 times", and "if it is 1000 kbps or less, the extension magnification is increased by 10 times", may be previously determined between the nodes **100** by the extension negotiation. However, even in this case, in order to synchronize between the node **100***a* and the node **100***b* from which extension magnification of the application key is strictly changed, the information of the ID of the application key may be exchanged between the nodes **100**.

Description has been given herein of the embodiment in which the node **100***a* and the node **100***b* communicate through the node communication unit **204**. However, the extension magnification and the algorithm of the application key may be determined by using other paths.

An example of extension algorithm of an actual application key will be described below. These are one of the examples, and any algorithm is applicable as long as the algorithm is capable of extending the length of an application key.

FIG. **5** is a diagram illustrating an example of a simple extension method of an application key. The algorithm in FIG. **5** is an algorithm in which the application key is extended by replacing data included in the application key with data (conversion data), which has been determined and extended according to a pattern of the data. In the extension algorithm in FIG. **5**, simply, when bit data of the application key before extension is "0", bit data of the extended application key is replaced by "000". Moreover, when the bit data of the application key before extension is "1", the bit data of the extended application key is replaced by "111". In this example, the extension magnification of the application key is three times.

As another example, when the bit data of the application key before extension is "0", the bit data of the extended application key may be replaced by "0011001100", and when the bit data of the application key before extension is "1", the bit data of the extended application key may be replaced by "1100110011". In this example, the extension magnification becomes 10 times. In this way, the extension of the application key can be easily executed whatever times the extension magnification is.

FIG. **6** is a diagram illustrating an example of an extension method of an application key utilizing a cryptograph processing. The extension algorithm in FIG. **6** is an extension algorithm in which, using an application key as a parameter of the cryptograph processing, a cryptogram obtained by executing the cryptograph processing on a plaintext is generated as an extended key. FIG. **6** illustrates an example of an extension method using a cryptographic algorithm of "AES-128 bit CBC mode".

In this case, the extension unit **105** first cuts out every 16 bytes of the application key (before extension). The cut-out data is IV1, Key1, IV2, Key2, . . . in order from the top. For example, when the extension unit **105** encrypts certain 32K-byte data (target data) according to the AES-128 bit where IV1 and Key1 respectively serve as IV (Initial Vector) and key Key, 32K-byte data (Appkey1) is obtained. The extension unit **105** forms this data as a portion of the extended application key (extended key). By sequentially performing such processing in order of an IV1 and Key1 pair, an IV2 and Key2 pair, . . . and so on, data for 32 bytes (16-byte IV and 16-byte Key) can be sequentially extended to data for 32K bytes. In this case, the extension processing with the extension magnification of 1000 times is executed. The target data to be encrypted may be any data. For instance, all values of zero, or values which have been separately cut out beforehand from the application key (before extension) may be used as the target data. By adjusting a data length of the target data, a block length utilized in the AES, or the like, the extension magnification can be variously changed.

Next, error processing will be described. The node **100**, which has received the communication starting request including the application key request from the application **200**, can execute provision of the application key which satisfies the request from the application **200** according to the aforementioned processing. However, due to the restrictions of executable extension magnification and the like, there is a possibility that a throughput requested by the application cannot be responded. For example, simply, there is a case in which a requested large extension magnification cannot be supported. Further, when the extension magnification is excessively large, since security (safety) of the application key is reduced, there is also a possibility that the node **100** does not permit the large extension magnification.

In such conditions, several methods can be considered to deal with the behaviors of the node **100**. For example, since provision of the application key at the requested throughput cannot be executed, the node **100** may be configured in such a manner that the node **100** gives an error reply to the communication request from the application and does not permit the connection. The node **100** may also be configured in such a manner that the node **100** starts to exchange the application key at the maximum possible extension magnification and replies to the application that the requested request throughput cannot be achieved and the request throughput which can be actually utilized.

Further, even when the negotiation of the extension method data is implemented between the nodes **100**, the maximum values of the extension magnifications permitted by the node **100***a* and the node **100***b* may be different. Then, in such a case, it is possible that the node **100***b* cannot achieve the extension magnification notified from the node **100***a* and needs to perform extension of the application key at the extension magnification smaller than the notified extension magnification. In this case, the node **100***b* may give error notification that the node **100***b* cannot deal with the negotiation of the extension magnification and may cancel starting or changing of the extension by driving the negotiation into failure. Alternatively, another method may be considered in which the node **100***b* notifies the node **100***a* of the maximum possible extension magnification, so that the maximum possible application key extension between the node **100***a* and the node **100***b* can be achieved as well.

As described above, according to the present embodiment, even if the sharing speed of the application key shared between the nodes is restricted, the node can provide the application key to the application faster and more stably.

Next, a hardware configuration of an apparatus (nodes, applications) according to the present embodiment will be described using FIG. **7**. FIG. **7** is an explanatory diagram illustrating the hardware configuration of the apparatus according to the present embodiment.

The apparatus according to the present embodiment includes a control device, such as a CPU (Central Processing Unit) **51**, a storage device, such as a ROM (Read Only Memory) **52** and a RAM (Random Access Memory) **53**, and a communication I/F **54** which communicates by connecting to a network, and a bus **61** which connects each device.

A program executed by the apparatus according to the present embodiment is provided by previously incorporating in the ROM **52** or the like.

The program executed by the apparatus according to the present embodiment may be configured in such a manner that the program is recorded in an installable or executable format file on a recording medium readable by a computer, such as a CD-ROM (Compact Disk Read Only Memory), a flexible disk (FD), CD-R (Compact Disk Recordable), DVD (Digital Versatile Disk), or the like and is provided as a computer program product.

Further, the program executed by the apparatus according to the present embodiment may be configured in such a manner that the program is provided by storing on a computer connected to a network, such as the Internet, and downloading via the network. Moreover, the program executed by the apparatus according to the present embodiment may be configured in such a manner that the program is provided or distributed via the network, such as the Internet.

The program executed by the apparatus according to the present embodiment can cause the computer to function as each device of the above-described apparatus. In this computer, the CPU **51** can read out and execute the program on a main storage external apparatus from a computer readable storage medium.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

What is claimed is:

1. A communication apparatus, comprising:

a hardware processor that

shares a first cryptographic key with an external apparatus connected via a link, and further generates one or more second cryptographic keys and shares the one or more second cryptographic keys with the external apparatus through secret communication using the first cryptographic key;

generates an extended key by extending a length of one of the second cryptographic keys;

transmits the extended key to a first application which cryptographically communicates with a second application using the extended key as a cryptographic key, the external apparatus providing the extended key to the second application;

determines an extension method, which is executable in common with the external apparatus, from among a plurality of extension methods of the second cryptographic keys;

transmits, to the external apparatus, identification information identifying one of the second cryptographic keys that starts execution of the determined extension method; and

generates the extended key by extending the length of the one of the second cryptographic keys according to the determined extension method, by starting the execution of the determined extension method to the one of the second cryptographic keys identified by the identification information,

wherein the hardware processor transmits to the external apparatus extension method data including a priority order of the extension methods, receives from the external apparatus the extension method determined by the external apparatus based on the priority order from among the extension methods indicated by the extension method data, and determines the received extension method as the extension method which is executable in common with the external apparatus.

2. The apparatus according to claim **1**, wherein the processor transmits to the external apparatus extension method data indicating at least one of executable extension methods, receives from the external apparatus the extension method determined by the external apparatus from among the extension methods indicated by the extension method data, and determines the received extension method as the extension method which is executable in common with the external apparatus.

3. The apparatus according to claim **1**, wherein the processor further determines an extension method of the second cryptographic keys based on a throughput of the second cryptographic keys requested by the first application and based on a sharing speed of at least one of the first cryptographic key and the second cryptographic keys with the external apparatus.

4. The apparatus according to claim **3**, wherein, when the requested throughput is changed, the processor determines the extension method based on the changed throughput and the sharing speed.

5. The apparatus according to claim **3**, wherein, when at least one of the sharing speed and condition information indicating a condition of sharing processing of at least one of the first cryptographic key and the second cryptographic keys with the external apparatus is changed, the processor determines the extension method based on the throughput and the sharing speed.

6. The apparatus according to claim **1**, wherein the processor generates the extended key by replacing data included in one of the second cryptographic keys with conversion data which is determined according to a pattern of the data and which is longer than the data.

7. The apparatus according to claim **1**, wherein the processor generates, as the extended key, a cryptogram obtained by executing a cryptograph processing on a plaintext, the cryptograph processing being executed by using one of the second cryptographic keys as a parameter.

8. The apparatus according to claim **1**, wherein the processor shares the second cryptographic keys with the external apparatus through the secret communication via one or more other communication apparatuses.

9. A communication system including a plurality of communication apparatuses, each of the communication apparatuses comprising:

a hardware processor that

shares a first cryptographic key with another communication apparatus connected via a link, and further generates one or more second cryptographic keys and shares the second cryptographic keys with the other communication apparatus through secret communication using the first cryptographic key;

generates an extended key by extending a length of one of the second cryptographic keys;

transmits the extended key to a first application which cryptographically communicates with a second application using the extended key as a cryptographic key, the other communication apparatus providing the extended key to the second application;

determines an extension method, which is executable in common with the other communication apparatus, from among a plurality of extension methods of the second cryptographic keys;

transmits to the other communication apparatus, identification information identifying one of the second cryptographic keys that starts execution of the extension method; and

generates the extended key by extending the length of the one of the second cryptographic keys according to the determined extension method, by starting the execution of the determined extension method to the one of the second cryptographic keys identified by the identification information,

wherein the hardware processor transmits to the other communication apparatus extension method data including a priority order of the extension methods, receives from the other communication apparatus the extension method determined by the other communication apparatus based on the priority order from among the extension methods indicated by the extension method data, and determines the received extension method as the extension method which is executable in common with the other communication apparatus.

10. A computer program product comprising a non-transitory computer-readable medium containing a computer program that causes a computer execute:

sharing a first cryptographic key with an external apparatus connected via a link, and further generating one or more a second cryptographic keys and sharing the second cryptographic keys with the external apparatus through secret communication using the first cryptographic key;

generating an extended key by extending a length of one of the second cryptographic keys;

transmitting the extended key to a first application which cryptographically communicates with a second application using the extended key as a cryptographic key the external apparatus providing the extended key to the second application;

determining an extension method, which is executable in common with the external apparatus, from among a plurality of extension methods of the second cryptographic keys;

transmitting to the external apparatus, identification information identifying one of the second cryptographic keys that starts execution of the extension method; and

generating the extended key by extending the length of the one of the second cryptographic keys according to the determined extension method, by starting the execution of the determined extension method to the one of the second cryptographic keys identified by the identification information,

wherein said transmitting to the external apparatus transmits extension method data including a priority order of the extension methods, receives from the external apparatus the extension method determined by the external apparatus based on the priority order from among the extension methods indicated by the extension method data, and determines the received extension method as the extension method which is executable in common with the external apparatus.

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